Stratospheric Aerosol and Gas Experiment II CD-ROM Atlas of Global Monthly Aerosols, Ozone, NO_2, Water, Vapor, and Relative Humitidy (1985–1993)

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Received 7 October 1996; accepted 16 January 1997.

ABSTRACT: Individual profile measurements from the Stratospheric Aerosol and Gas Experiment II (SAGE II) instrument aboard the Earth Radiation Budget Satellite have been used to create latitude-longitude maps of monthly mean aerosols, ozone, water vapor, relative humidity and NO_2 on up to 14 standard pressure levels. Color maps and gridded data from 1985 through 1993 are available on a CD-ROM that can be obtained from the Distributed Active Archive Center (DAAC) at NASA Langley Research Center. Examples are shown of the ozone hole and related phenomenon, and aerosol loading associated with the Mount Pinatubo volcano. By presenting the data in this visible and easy-to-use format, we hope that it will reach a larger community and result in better understanding of atmospheric aerosols and trace gases. Similar presentations will be generated for SAGE III data, expected to begin in 1998 as part of the Earth Observing System (EOS).

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KEYWORDS: Atmospheric composition and structure; Middle atmosphere—composition and chemistry; Troposphere—composition and chemistry; Remote sensing

1. Introduction

Atmospheric aerosols, ozone, water vapor, and NO_2 all play important roles in global radiative and atmospheric chemical processes. Natural activities, for example, major volcanic eruptions, can inject gaseous sulfur dioxide, dust, and other chemicals into the upper atmosphere and therefore affect the radiative forcing of the climate system. Human activities also perturb the balance of atmospheric aerosols and trace gases.

Since 1984, the Stratospheric Aerosol and Gas Experiment II (SAGE II) instrument aboard the Earth Radiation Budget Satellite (ERBS) has been monitoring atmospheric profiles of aerosols, ozone, water vapor, and NO_2 in the upper troposphere and stratosphere using a limb occultation technique between approximately 80°N and 80°S. The SAGE II mission provides measurements of profiles of atmospheric extinction (km^{-1}) from the upper stratosphere to the cloud top or surface boundary layer in the case of clear skies. These extinction data are inverted into aerosol extinction at each of four spectral channels (385, 453, 525, and 1020 nm), ozone, water vapor and NO_2 volumetric mixing ratios and number densities as a function of latitude, longitude, altitude, and time (Chu and McCormick, 1979; Chu et al., 1993). Corresponding temperature and pressure values (and the altitude of the tropopause) for each SAGE II profile are obtained from the National Meteorological Center (NMC) (now known as the National Centers for Environmental Prediction) to calculate neutral density and convert between altitude and pressure. The entire SAGE II profile data set is continuously archived by the NASA Langley Research Center at the National Space Sciences Data Center. More information on SAGE II and the individual species retrievals can be found in summary papers by McCormick et al. (McCormick et al., 1979), Mauldin et al. (Mauldin et al., 1985), Russell and McCormick (Russell and McCormick, 1989), Rind et al. (Rind et al., 1993), and Cunnold et al. (Cunnold et al., 1989, , 1991).

In this paper we discuss the preparation and availability of a CD-ROM displaying color images (GIF format) and gridded data (ASCII format) of the SAGE II data products. Data have been interpolated and gridded onto standard pressure levels. The CD-ROM provides easy access to monthly averaged SAGE II retrievals for a variety of purposes, including quick-look usage and comparisons with other data sets.

2. Data processing and error discussion

While the individual profiles represent the fundamental data retrieval, an overall summary of the data characteristics can be better provided by considering the global species distributions at standard pressure levels. To produce such maps, we first interpolated the data (version 5.93) from individual profiles to at most 14 pressure levels (700, 500, 300, 200, 150, 100, 70, 50, 30, 10, 5, 2, 1, and 0.4 mbar (mb). The original profile data product has a vertical resolution of 1 km.

As an occultation instrument, SAGE II retrievals occur only during sunrise and sunset, producing 30 profiles per day. The horizontal footprint for each retrieval is approximately 200 km in the longitudinal direction (along line of sight), and 0.5 km latitudinally (perpendicular to line of sight). Given the sparse nature of the data product we grid the data into boxes of size $7.8° \times 10°$ (latitude $\times$ longitude), averaging over an entire month. Monthly mean gridded data therefore contain all available retrievals within each $7.8° \times 10°$ box. This resolution is a compromise to provide both maximum global coverage and yet maintain reasonably good spatial resolution consistent with the individual data points.

For presentation purposes an additional procedure involves interpolation between missing grid boxes. If a grid with zero profiles is surrounded by at least one grid with valid data, the blank grid is assigned the mean value over all available neighboring points (up to 8 points); otherwise, the grid is left blank. To avoid misinterpretation associated with this procedure, the number of observations used to produce each grid box value is included in the data set.

Monthly maps at up to 14 pressure levels for the years 1985–1993 have been prepared for the standard product retrievals: aerosols at the four different wavelengths, and ozone, water vapor (not available after June 1991), and NO_2 mixing ratios. In addition, for easy reference the corresponding NMC temperature, geometrical height and tropopause altitude are also shown. The relative humidity values have also been calculated from the water vapor mixing ratio and the NMC temperature data. The column-integrated stratospheric optical thickness at 1020 nm, down to 2 km above the tropopause, is shown as well.

Though the gridded data and images were created for a quick scan of monthly retrievals, the data may not provide a true monthly average due to the sparse number of observations. Users should be aware of this when interpreting the data results and should consult the observation number data file. The gridded data can be used to create seasonal, annual, and multiyear climatologies, which should increase its geographic representativeness.

Not all of the original profiles were used to produce the monthly retrievals. Profiles that are flagged to be anomalous by the SAGE data processing team were not included in the gridded data sets. No sunrise data were included for NO_2. Some gridded data exist only at certain levels, for example, aerosol extinction at 453 nm begins only at 200 mb and ends at 5 mb because of signal-to-noise problems. The retrieval errors for each of the data types are discussed in the respective papers introducing the data; in the examples shown below, no level is shown where the measurement error exceeds 25%.

3. Data presentation

The data presented includes monthly averaged visual images, the actual grid mean values, and the number of observations for each grid box location. The gridded data were mapped using NCAR GRAPHICS (3.0) contouring packages implemented at NASA GISS. All images are created using the popular Graphical In-

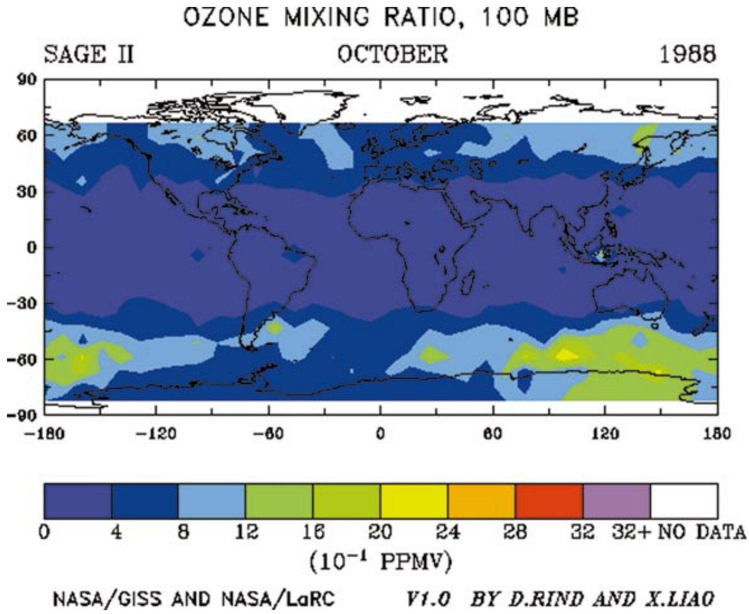

Figure 1a. Ozone maps for October 1988 for 100 mbar (mb). Note the change in scales with altitude for presentation purposes.

terchange Format (GIF), which is easily accessible with many different graphics viewing packages. For convenience we have made three shareware GIF graphics viewers available (for PCs, UNIX workstations and Macintosh computers). Printing of these charts is normally available with most GIF graphics viewing software. We have also included an NCAR GRAPHICS program which allows for different projections, dimensions and many other user specifications.

The gridded data and number of measurements are in ASCII format, which should be readily accessible. For reference we have also supplied two simple FORTRAN programs whose source codes display the formats needed for the data retrieval. A more detailed description of data availability and methods to access them is given in the booklet which accompanies the CD-ROM package.

4. Examples

For illustration purposes we show two sets of examples. Note that in both cases, because of the nature of SAGE II sampling, the monthly mean values represent only the retrieval opportunities, which may differ from a true monthly average.

The first example is for October 1988. Figure 1 gives the SAGE II ozone distribution at levels varying from 100 to 0.4 mb (Figure 1a–Figure 1i). The most obvious features include the increase in ozone with altitude, and the minimum over the western Antarctic region popularly known as the Antarctic ozone hole. The vertical extent of the ozone hole can be quite accurately assessed by examining the different levels. One advantage of the SAGE data set is the ability to

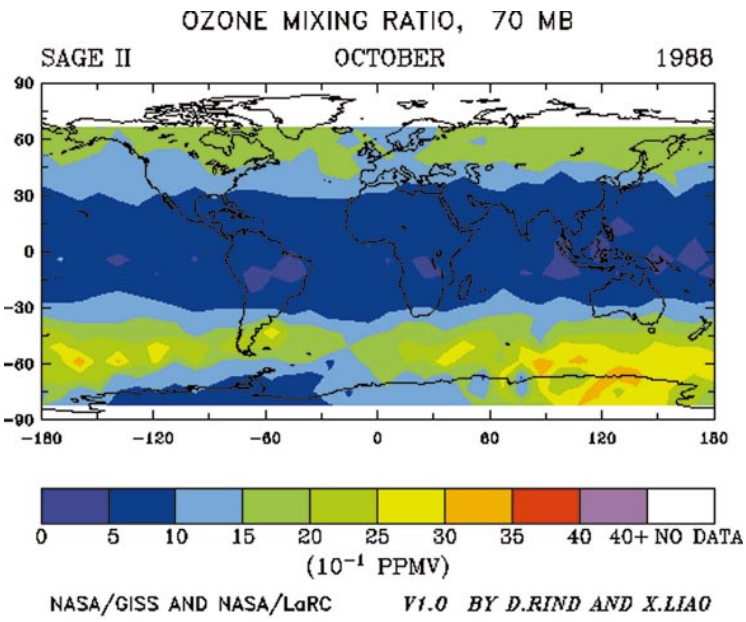

Figure 1b. Same as Figure 1a, except for 70 mb.

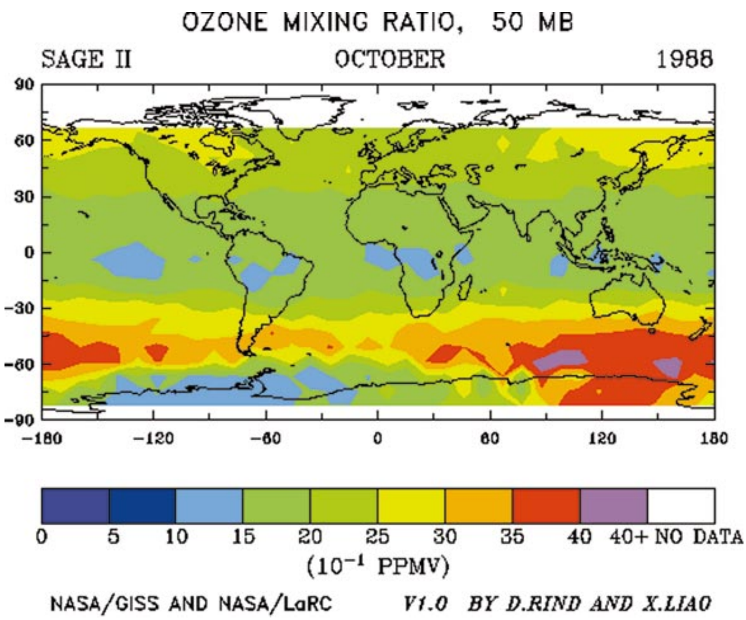

Figure 1c. Same as Figure 1a, except for 50 mb.

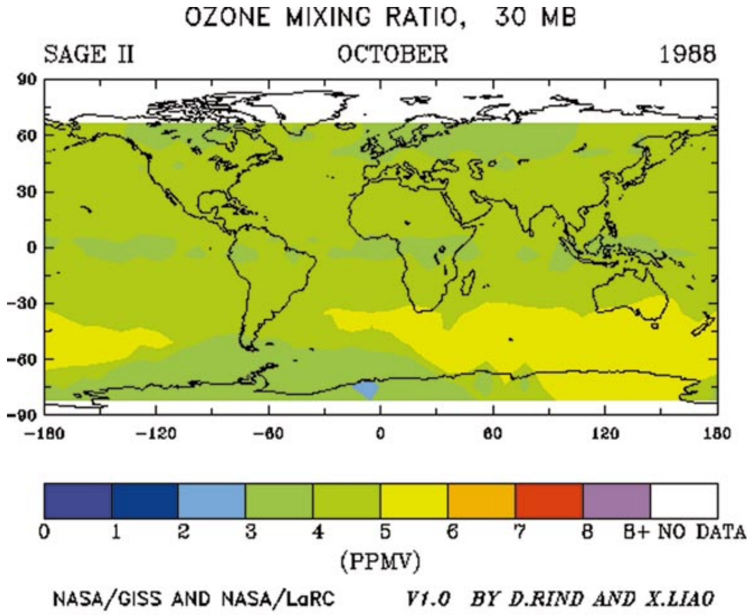

Figure 1d. Same as Figure 1a, except for 30 mb.

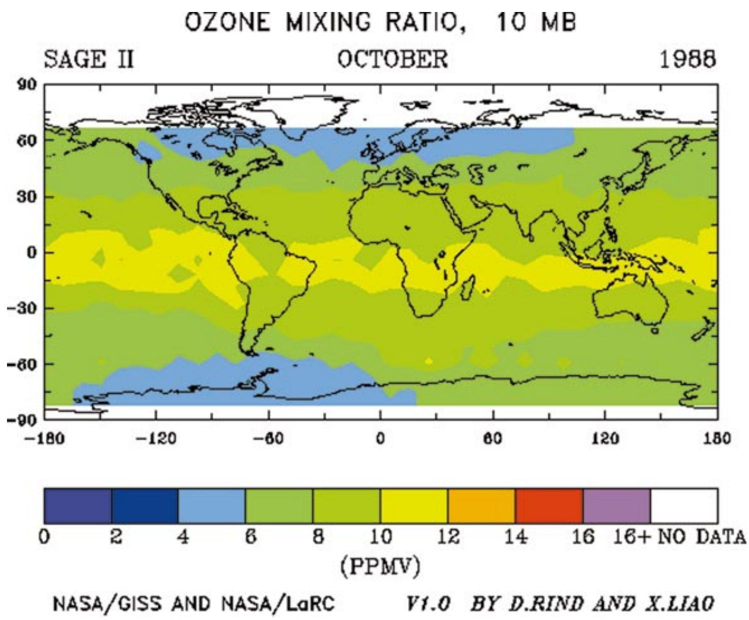

Figure 1e. Same as Figure 1a, except for 10 mb.

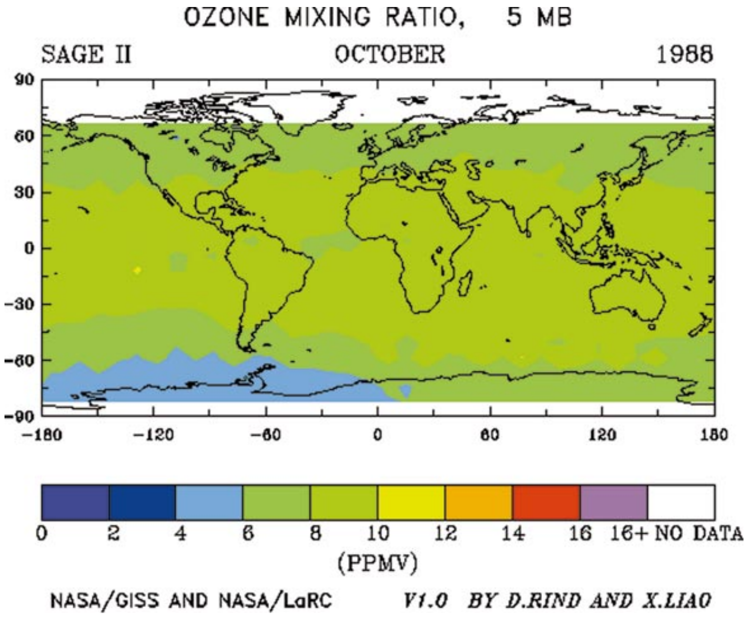

Figure 1f. Same as Figure 1a, except for 5 mb.

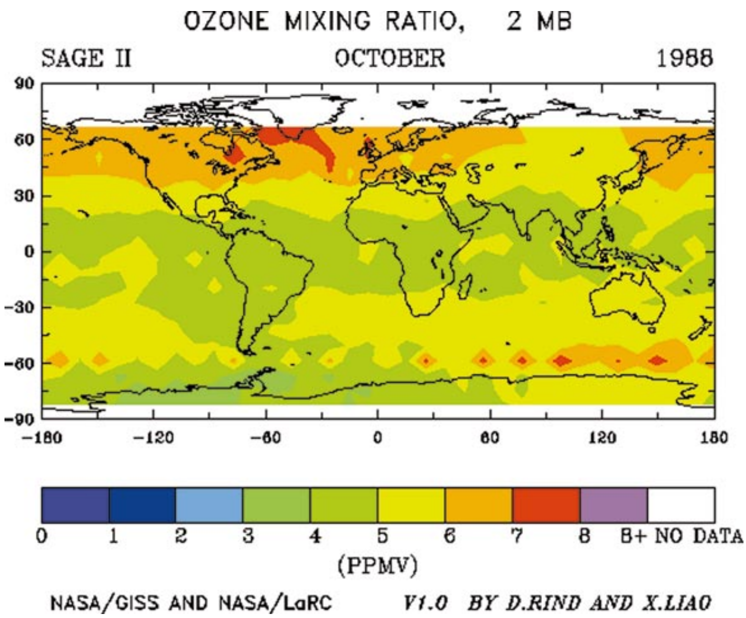

Figure 1g. Same as Figure 1a, except for 2 mb.

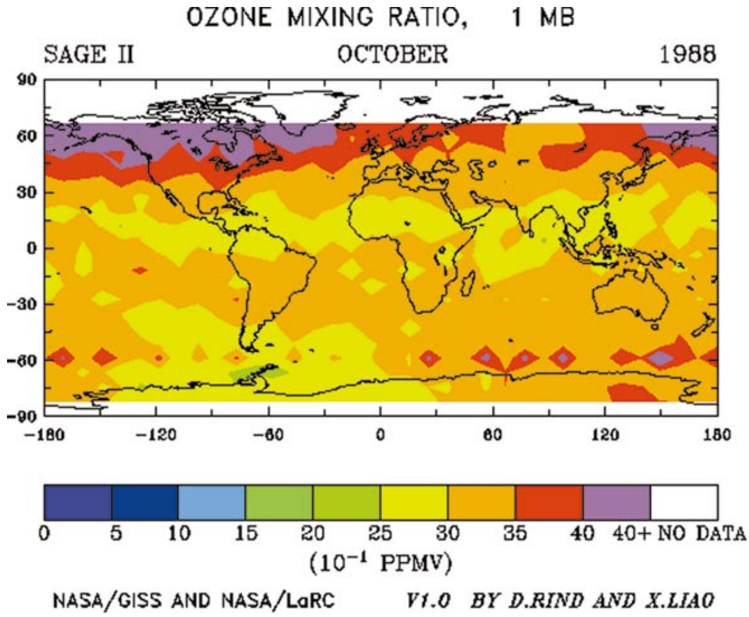

Figure 1h. Same as Figure 1a, except for 1 mb.

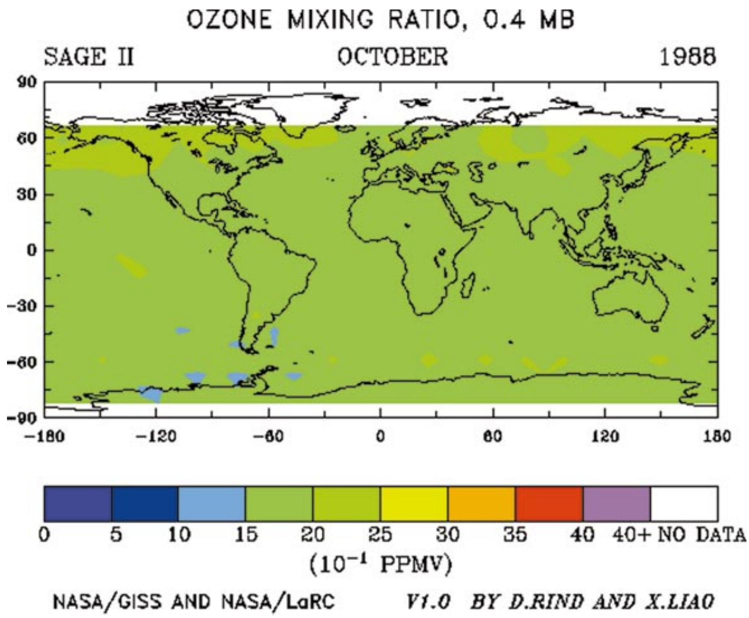

Figure 1i. Same as Figure 1a, except for 0.4 mb.

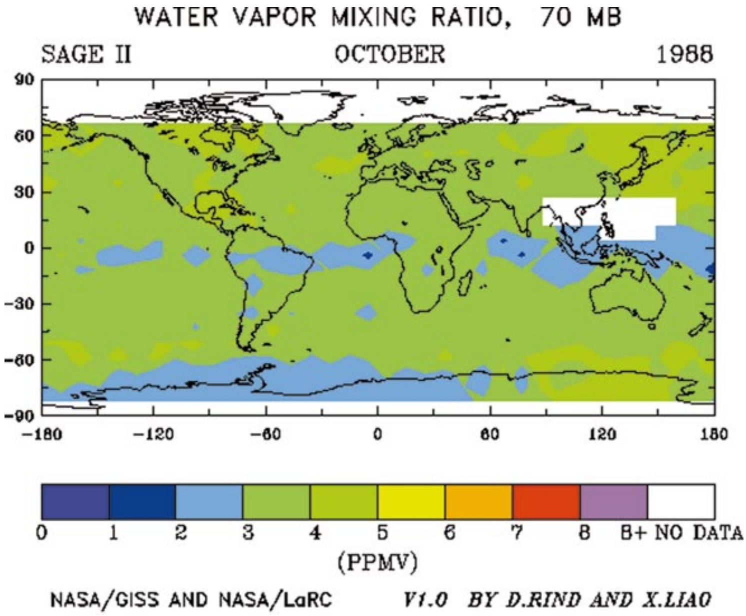

Figure 2a. Water vapor at 70 mb in October 1988.

depict the vertical variation of species such as ozone, which complements other satellite observations such as total ozone mapping spectrometer (TOMS).

Figure 2 gives the corresponding water vapor at 70 mb (Figure 2a) NO_2 at 30 mb (Figure 2b), the 70 mb temperature from NMC corresponding to the SAGE II retrievals (Figure 2c) and the SAGE II geometrical height (Figure 2d) calculated at the 70mb level with the aid of NMC data. In the southern polar vortex region (low geometrical height) the air is cold and shows minima in all three trace gases, consistent with expectations. However, as noted in World Meteorological Organization (World Meteorological Organization, 1995, p. 7), despite "extensive observational evidence for dehydration and denitrification," the underlying microphysical mechanisms that control particle formation and sedimentation in the ozone hole region "have not been adequately described." The variation with month and altitude, as well as interannual variations in all these quantities, are readily visible in the data set.

As a second example, Figure 3 shows the stratospheric column optical depth at 1020 nm wavelength for the periods of growth of the Mount Pinatubo aerosol peak. The first image (Figure 3a) shows the pre-Pinatubo aerosol loading, and the following figures (Figure 3b for July, Figure 3c for September, and Figure 3d for October) display the spread of the volcanic aerosol in both hemispheres for 4 months following the eruption.

Users can access the gridded data and obtain different statistics which can be plotted in addition to the images shown. For example, Figure 4 gives the variation of the altitude of the top of the dominant aerosol as a function of latitude and time. Before the Pinatubo eruption, the aerosol top was associated with cloud

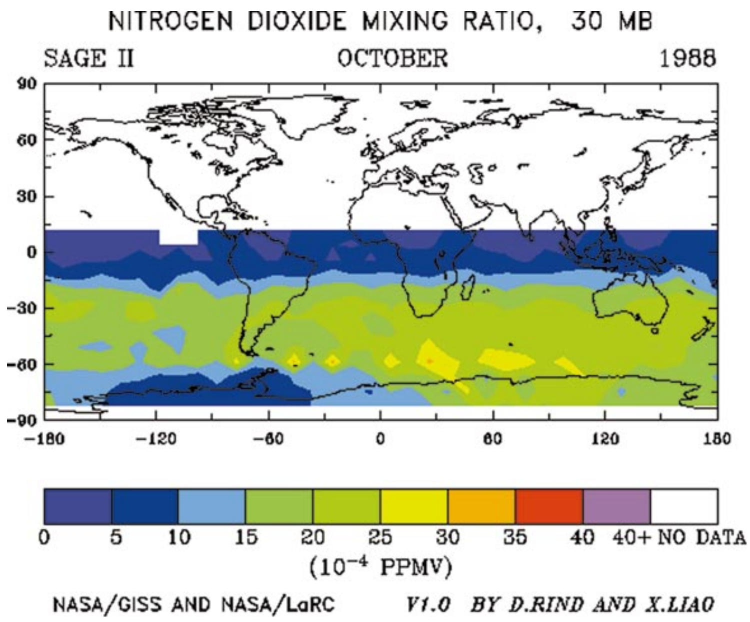

Figure 2b. NO_2 at 30 mb in October 1988.

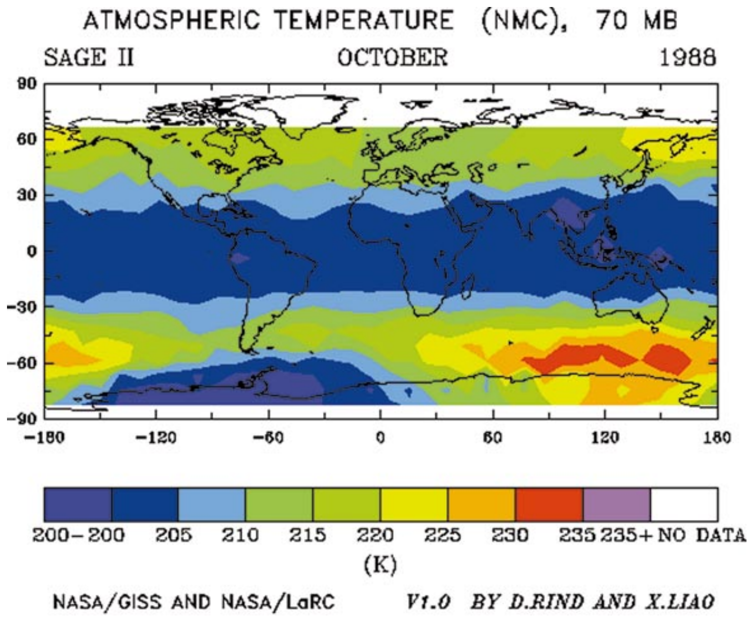

Figure 2c. Temperature at 70 mb (from NMC) for October 1988.

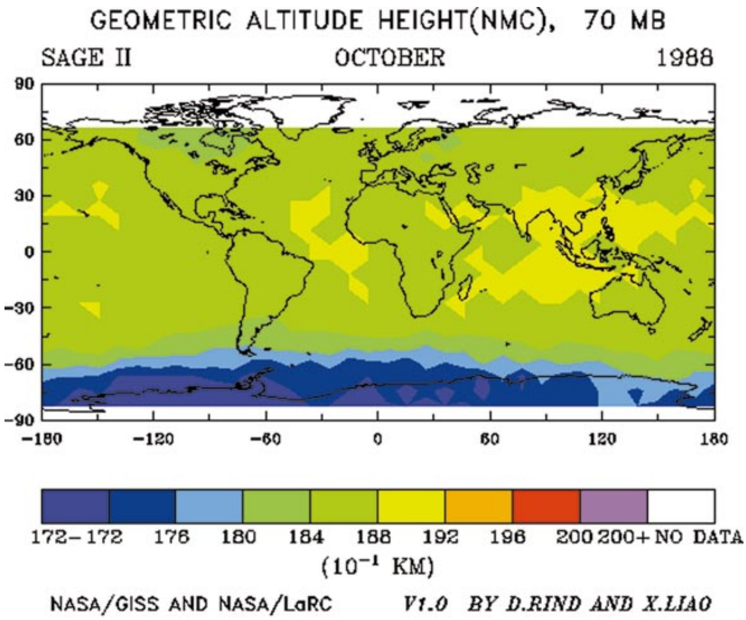

Figure 2d. Geometrical height at 70 mb (with NMC data) in October 1988.

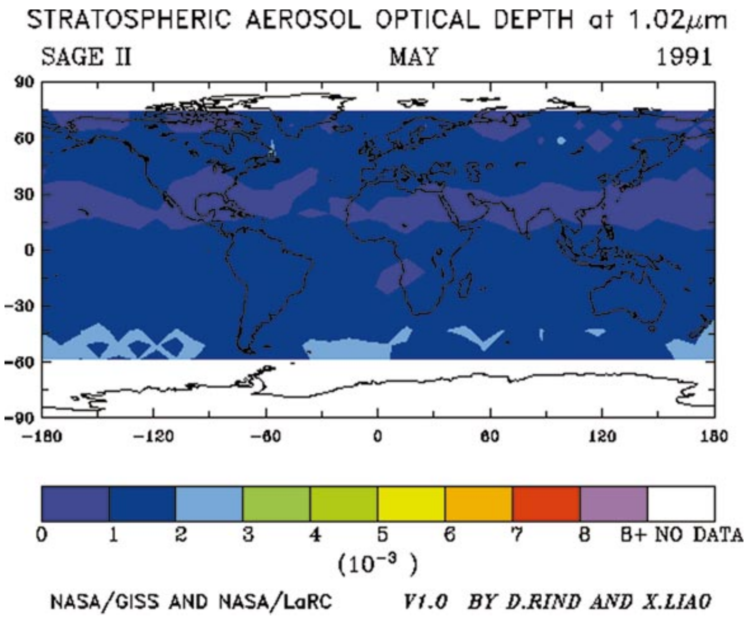

Figure 3a. Variation of 1020 nm stratospheric optical depth as a function of time, before and after the Pinatubo event for May 1991.

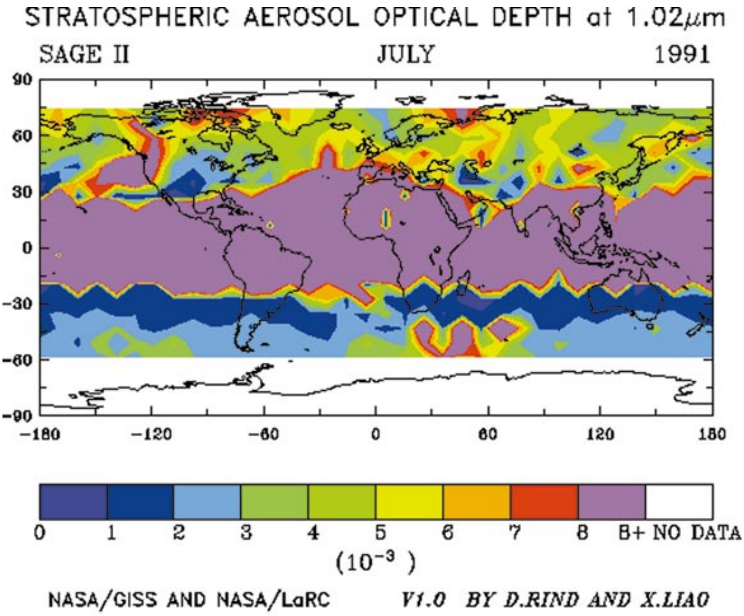

Figure 3b. Same as Figure 3a, except for July 1991.

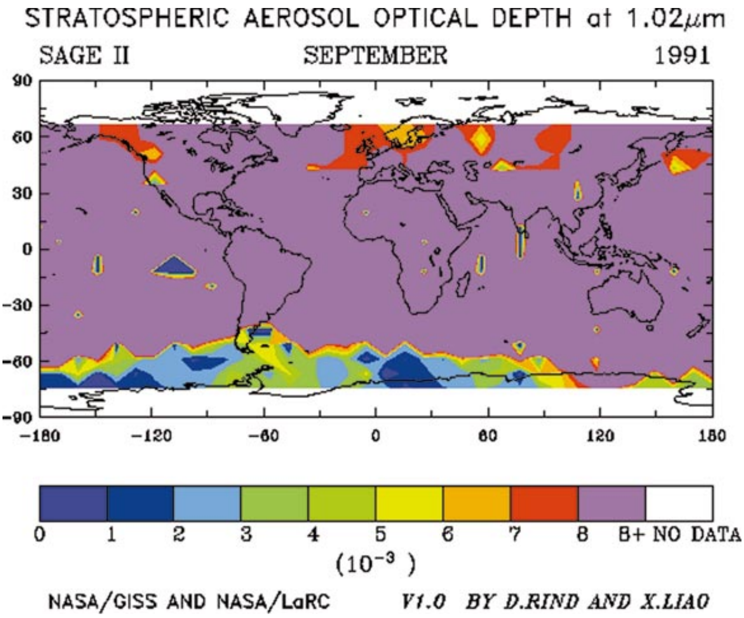

Figure 3c. Same as Figure 3a, except for September 1991.

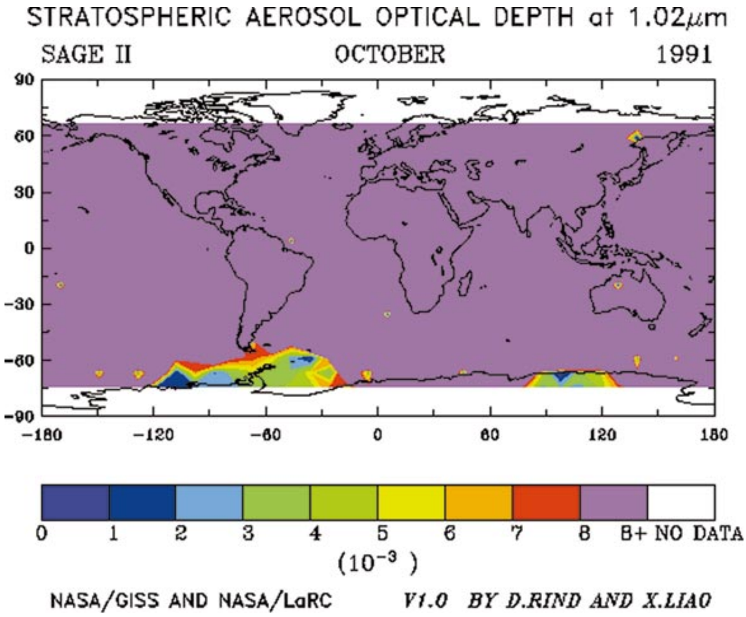

Figure 3d. Same as Figure 3a, except for October 1991.

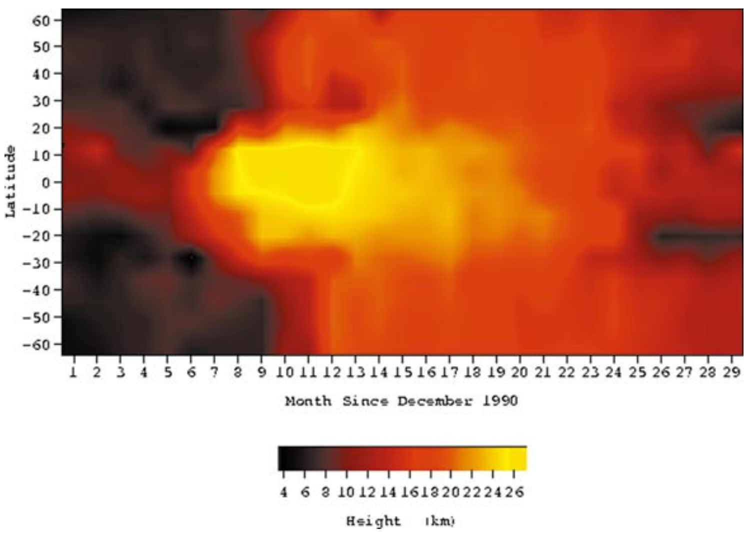

Figure 4. Variation of altitude of the 1020 nm aerosol saturation extinction with latitude and time. Before June of 1991 the extinction is associated with cloud cover and for the next 20 months with the Pinatubo volcano.

cover in the troposphere. After Pinatubo, the top rose to 26 km in the tropics and to less than 20 km in the extratropics before slowly descending with time.

5. Availability

The SAGE II CD-ROM will be available from the Langley DAAC beginning in the winter of 1996. Images are also available from the NASA/GISS World Wide Web home page (http://www.giss.nasa.gov).

The data as presented go only through 1993; SAGE II is continuing to take measurements (as of August 1996) and the additional data will eventually be gridded and mapped. Internet users can obtain update information from David Rind or Xiaohan Liao.

In addition, SAGE III will be launched during 1998 and will retrieve similar parameters. An equivalent SAGE III CD-ROM is currently anticipated.

Acknowledgments. Pat McCormick and Bill Chu of NASA/LaRC provided encouragement and constructive comments on this project. Programming support was provided by NASA/GISS and NASA/LaRC personnel: Jean Lerner, Jeff Jonas and Reto Ruedy gave system support and graphics programming advice; William Kovari contributed programming assistance, and Paula Detweiler provided product testing; Rich Healy and Junhong Wang helped with NCAR GRAPHICS programming. Erwoon Chiou supplied access to updated water vapor data. Robert Schmunck made the images available through the World Wide Web GISS home page. John Olson provided administrative assistance in the mastering of the CD-ROM. Support for this effort came from SAGE III funding, Pat McCormick P.I.

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